Detection of High Rate STBC in Frequency Selective m- Nakagami Fading Environment

Devendra Kumar[1], Nandkishor S Vansdadiya[1], Amit Kumar Kohli[1]
[1]Scholar, Electronics and Communication Dept., Thapar University, Patiala
E-mail- devchauhan151188@gmail.com

Abstract- In this article, we concerned with the performance of high rate space time block code (STBC) scheme for Frequency selective fading Environment. Due to large channel delay spread in Frequency selective channel inter symbol interference (ISI) occurred. In high rate STBC, ISI occurs due to loss of 'quasi – static' assumption and Classical Zero forcing (ZF) receiver produces error floor in Bit error rate (BER) performance. In this article we evaluate and proposed low Complexity Zero forcing which reduce the complexity of receiver for detection of high rate STBC and evaluate the performance in m–Nakagami fading environment.

Keywords- *Space time block code (STBC), Inter symbol interference (ISI), Zero forcing (ZF).*

Introduction

A simple and powerful diversity technique using two transmit antennas was first proposed by Alamouti Space–time block-coding (STBC) scheme has been proposed in several wireless application due to its many attractive features [1]. First one, at full transmission rate, it achieves full spatial diversity for any signal constellation with 2 transmit antennas and. Second, it does not require channel side information at the transmitter. Third, maximum likelihood decoding of STBC done by simple linear processing. The range and data rate of wireless networks is limited. To enhance the data rates and the quality, multiple antennas can be used at the receiver to obtain the diversity. By utilizing multiple antennas at transmitter and receiver, significant capacity advantages can be obtained in wireless system. In a Multiple Input Multiple Output (MIMO) system, multiple transmit and receive antennas, can elevate the capacity of the transmission link. This extra capacity can be utilized to enlarge the diversity gain of the system. This results in development of Lucent's "Bell-Labs layered space-time" (BLAST) architecture [5]-[6] and space time block codes (STBCs) [1]–[7] to attain some of this capacity

In high rate ($rate = \frac{5}{4}$) full diversity orthogonal STBC for QAM and 2 transmit antennas(Tx) by expanding the signalling set from the set of quaternions used in Alamouti[1] code.To maximizing full-diversity, selective power scaling of information symbols is used while maximizing the coding gain(CG) and minimizing the transmitted signal peak to minimum power ratio (PMPR). Analytically we derives optimum power scaling

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factor and we seen that it achives better performance with the help of rotation of constellation points, decoding is performed using low complexity maximum likelihood decoding algorithm[2].

After studying the literature we came to know that in [3] They have designed high rate STBC system, by not considering loss of 'quasi-static' assumption due to frequency selectivity phenomenon of channel. Due to frequency selectivity of channel causes ISI which results in error floor in bit error rate. In section I (A) we describe the high rate STBC system for frequency flat case, in section I(B) to compact the effect of ISI in frequency selective environment, we proposed low comlexity zero forcing which reduces the complexity of equalizer. In section II and III, we describe the simulation results in m-Nakagami fading environment and Conclusion respectively.

System Model of High rate STBC:

The simplest complex orthogonal design is the 2×2 code

$$G_1(\mathrm{x}_1,\mathrm{x}_2)\to\begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix}$$

find out by Alamouti [1] where $(.)*$ denotes the complex conjugate transpose. This code accomplishes rate-1 at full diversity. The correspondence between Alamouti matrices and means of quaternion's is that the set of Alamouti matrices is closed under inversion, addition and multiplication. Consider the set G_2 of **x** given by 2×2 orthogonal matrices

$$G_2(\mathrm{x}_1,\mathrm{x}_2)\to\begin{pmatrix} x_1 & x_2 \\ x_2^* & -x_1^* \end{pmatrix}=\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}G_1$$

Transmission model:

Different antennas represented by the columns of G_1, different time slots represented by rows of G_1 and two symbols are transmitted in frequency selective fading environment. We use *QAM* modulation in this system, the transmission of space-time matrix is done based on either G_1 or G_2 according to an extra information bit of 1 or 0 respectively shown in Fig.1. To regain full-diversity, Strategy based on rotation of information symbols has been proposed. In this paper, we assume the information symbol in G_2 is divided only by a real scalar $K(>1)$ to ensure full-diversity, hence it is called selective power scaling. For QAM constellation of unit-radius, scaling leads to overall signal constellation consisting of two concentric circles of radius 1 and $\frac{1}{K}$ [4]. For the optimum power scaling factor K is to ensure full diversity for high-rate STBC. As K>1,

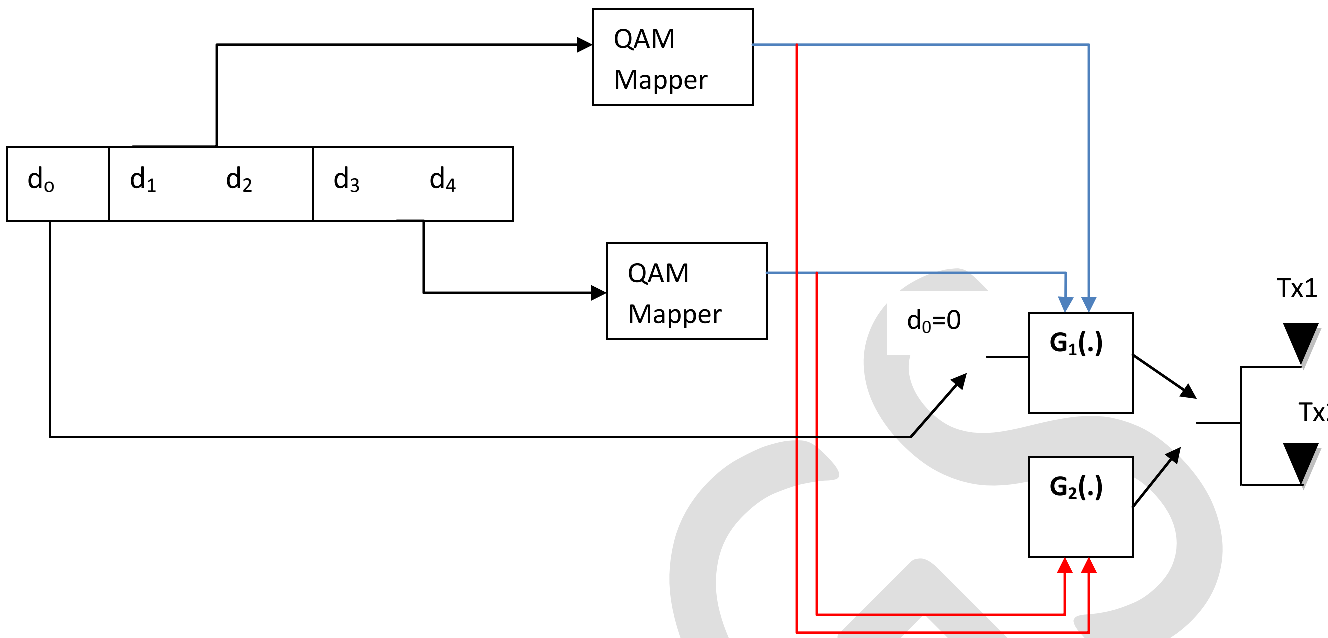

Fig. 1 Block diagram of rate-5/4 STBC for QAM Modulation

the average transmitted power is reduced as compared to the case of no scaling. Two important selection techniques for K are maximizing the CG and minimizing the PMPR due to power scaling. We select $K_{opt} = \sqrt{3}$ which is proposed in [3].

Received signal model of High rate STBC:

Time domain representation of received signal at receiver is denoted by

$$\underbrace{\begin{bmatrix} r_{1,t} \\ r_{1,t+1} \end{bmatrix}}_{\mathbf{R}} = \underbrace{\begin{bmatrix} h_{1,t} & h_{2,t} \\ h^{*}_{2,t+1} & -h^{*}_{1,t+1} \end{bmatrix}}_{\mathbf{H}} \underbrace{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}}_{\mathbf{X}} + \underbrace{\begin{bmatrix} n_t \\ n_{t+1} \end{bmatrix}}_{\mathbf{N'}} \tag{1}$$

And

$$\underbrace{\begin{bmatrix} r^{opt}_{1,t} \\ r^{opt}_{1,t+1} \end{bmatrix}}_{\mathbf{R_{opt}}} = \underbrace{\begin{bmatrix} \frac{h_{1,t}}{K} & \frac{-h_{2,t}}{K} \\ \frac{h^{*}_{2,t+1}}{K} & \frac{h^{*}_{1,t+1}}{K} \end{bmatrix}}_{\mathbf{H}_{opt}} \underbrace{\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}}_{\mathbf{X}} + \underbrace{\begin{bmatrix} n_t \\ n_{t+1} \end{bmatrix}}_{\mathbf{N'}} \tag{2}$$

Where $\mathbf{R}$ and $\mathbf{R_{opt}}$ are 2×2 matrix representations of the time domain received signals corresponding to transmitted code words in the form of G_1 and , respectively. $h_{i,t}, i = 1, 2$ is channel path gain from transmitter 1 and transmitter 2, respectively at t time instant.

For frequency flat condition :

Due to frequency flat nature of channel we can say that $h_{1,t} = h_{1,t+1}$ and $h_{2,t} = h_{2,t+1}$. Therefore received signal is represented from eq.(1) is

$$\begin{bmatrix} r_{1,t} \\ r_{1,t+1} \end{bmatrix} = \begin{bmatrix} h_{1,t} & h_{2,t} \\ h^*_{2,t} & -h^*_{1,t} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_t \\ n_{t+1} \end{bmatrix} \tag{3}$$

$$\mathbf{R} = \mathbf{HX} + \mathbf{N'}$$

$$\hat{\mathbf{R}} = \mathbf{H^H}(\mathbf{HX} + \mathbf{N'}) \tag{4}$$

Where $H^H H = \begin{bmatrix} |h_{1,t}|^2 + |h_{2,t}|^2 & 0 \\ 0 & |h_{1,t}|^2 + |h_{2,t}|^2 \end{bmatrix}$,

here off diagonal element of $\mathbf{H}^H\mathbf{H}$ is zero so there is no inter symbol interference. Similarly from eq.(2)

$$\begin{bmatrix} r^{opt}_{1,t} \\ r^{opt}_{1,t+1} \end{bmatrix} = \begin{bmatrix} \frac{h_{1,t}}{K} & \frac{-h_{2,t}}{K} \\ \frac{h^*_{2,t}}{K} & \frac{h^*_{1,t}}{K} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_t \\ n_{t+1} \end{bmatrix} \tag{5}$$

$$\mathbf{R}_{opt} = \mathbf{H}_{opt}\mathbf{X} + \mathbf{N'}$$

$$\hat{\mathbf{R}}_{opt} = \mathbf{H}^H_{opt}.(\mathbf{H}_{opt}\mathbf{X} + \mathbf{N'}) \tag{6}$$

Where $H^H_{opt} H_{opt} = \begin{bmatrix} \frac{1}{K^2}\left(|h_{1,t}|^2 + |h_{2,t}|^2\right) & 0 \\ 0 & \frac{1}{K^2}\left(|h_{1,t}|^2 + |h_{2,t}|^2\right) \end{bmatrix}$, here off diagonal element of $\mathbf{H}^H_{opt}\mathbf{H}$ is zero so there is no inter symbol interference.

Proposed Low complexity ZF receiver:

Due to frequency selectivity nature of channel, there is loss of quasi-static assumption caused ISI. We can say that $h_{1,t} \neq h_{1,t+1}$ and $h_{2,t} \neq h_{2,t+1}$. Therefore received signal is represented from eq.(1) is

$$\begin{bmatrix} r_{1,t} \\ r_{1,t+1} \end{bmatrix} = \begin{bmatrix} h_{1,\mathrm{t}} & h_{2,\mathrm{t}} \\ h^*_{2,\mathrm{t+1}} & -h^*_{1,\mathrm{t+1}} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_t \\ n_{t+1} \end{bmatrix}$$

$$\mathbf{R = HX + N'}$$

$$\mathbf{\hat{R} = H^H (HX + N')}$$

Where $H^H H = \begin{bmatrix} |h_{1,t}|^2 + |h_{2,t}|^2 & \in_1 \\ \in_2 & |h_{1,t}|^2 + |h_{2,t}|^2 \end{bmatrix}$, $\in_1 = h^*_{1,t} h_{2,t} - h_{2,t+1}.h^*_{1,t+1}$ and $\in_2 = h^*_{2,t} h_{1,t} - h_{1,t+1}.h^*_{2,t+1}$. Here off diagonal element of $\mathbf{H}^H\mathbf{H}$ is not zero so there is inter symbol interference due to loss of quasi-static assumption. To mitigate the effect of ISI we proposed Low Complexity Zero forcing (LZF).

$$\mathbf{\hat{R} = H}^{LZF}\mathbf{(HX + N')} \tag{7}$$

$$\mathbf{\hat{X}} = (\mathbf{H}^{LZF}\mathbf{H})^{-1}\mathbf{\hat{R}} \tag{8}$$

Where $H^{LZF} = \begin{bmatrix} h^*_{1,t} & \dfrac{h_{2,t+1}}{L_t} \\ h^*_{2,t} & -\dfrac{h_{1,t+1}}{L^*_t} \end{bmatrix}$ and $L_t = \dfrac{h_{2,t+1}.h^*_{1,t+1}}{h^*_{1,t}.h_{2,t}}$ $H^{LZF} H = \begin{bmatrix} |h^*_{1,t}|^2 + \dfrac{|h_{2,t+1}|^2}{L_t} & 0 \\ 0 & |h_{2,t}|^2 + \dfrac{|h_{1,t+1}|^2}{L^*_t} \end{bmatrix}$

Similarly from eq.(2) is given by

$$\begin{bmatrix} r^{opt}_{1,t} \\ r^{opt}_{1,t+1} \end{bmatrix} = \begin{bmatrix} \dfrac{h_{1,t}}{K} & \dfrac{-h_{2,t}}{K} \\ \dfrac{h^*_{2,t+1}}{K} & \dfrac{h^*_{1,t+1}}{K} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_t \\ n_{t+1} \end{bmatrix}$$

$$\mathbf{R_{opt} = H_{opt}X + N'}$$

$$\hat{\mathbf{R}}_{\mathbf{opt}} = \mathbf{H}_{\mathbf{opt}}^{\mathbf{H}}.(\mathbf{H}_{\mathbf{opt}}\mathbf{X} + \mathbf{N'})$$

Where $H_{opt}^{H}H_{opt} = \begin{bmatrix} \frac{1}{K^2}\left(|h_{1,t}|^2 + |h_{2,t+1}|^2\right) & \in_1^{opt} \\ \in_2^{opt} & \frac{1}{K^2}\left(|h_{1,t+1}|^2 + |h_{2,t}|^2\right) \end{bmatrix}$, $\in_1^{opt} = \frac{-h_{1,t}^{*}h_{2,t}}{K^2} + \frac{h_{2,t+1}.h_{1,t+1}^{*}}{K^2}$ and $\in_2^{opt} = \frac{-h_{2,t}^{*}h_{1,t}}{K^2} + \frac{h_{1,t+1}.h_{2,t+1}^{*}}{K^2}$. Here off diagonal element of $\mathbf{H}_{\mathbf{opt}}^{H}\mathbf{H}_{\mathbf{opt}}$ is not zero so there is inter symbol interference due to loss of quasi-static assumption. To mitigate the effect of ISI we proposed Low Complexity Zero forcing (LZF).

$$\hat{\mathbf{R}}_{opt} = \mathbf{H}_{opt}^{LZF}.(\mathbf{H}_{opt}\mathbf{X} + \mathbf{N'}) \tag{9}$$

$$\hat{\mathbf{X}}_{opt} = (\mathbf{H}_{opt}^{LZF}\mathbf{H}_{opt})^{-1}\hat{\mathbf{R}}_{opt} \tag{10}$$

$$H_{opt}^{LZF} = \begin{bmatrix} \frac{h_{1,t}^{*}}{K} & \frac{h_{2,t+1}}{K\cdot L_t} \\ \frac{-h_{2,t}^{*}}{K} & \frac{h_{1,t+1}}{K\cdot L_t^{*}} \end{bmatrix} \text{ and } H_{opt}^{LZF}H_{opt} = \begin{bmatrix} \frac{1}{K^2}\left(|h_{1,t}|^2 + \frac{|h_{2,t+1}|^2}{L_{t,opt}}\right) & 0 \\ 0 & \frac{1}{K^2}\left(\frac{|h_{1,t+1}|^2}{L_{t,opt}^{*}} + |h_{2,t}|^2\right) \end{bmatrix}$$

Applying Low complexity Zero forcing on eq.(7) and eq.(9) we generate two candidate solution namely, $\hat{\mathbf{X}}$ and $\hat{\mathbf{X}}_{opt}$ which are compared using $\left\|\mathbf{R}^{T} - [h_1 \quad h_2]\mathbf{X}^{\mathrm{T}}\right\|^2$ and $\left\|\mathbf{R}_{opt}^{T} - [h_1 \quad h_2]\mathbf{X}^{\mathrm{T}}\right\|^2$. The decoding of d_o follows directly once the decision between $\hat{\mathbf{X}}$ and $\hat{\mathbf{X}}_{opt}$ is made.

SIMULATION RESULTS:

Simulation results shown in this paper are verified using Matrix Laboratory v-7.5.0.The symbol error rate performance of two transmitter and one receiver antenna systems (high rate STBC) was investigated through computer simulation. We assume that channel state information (CSI) is perfectly known at receiver.

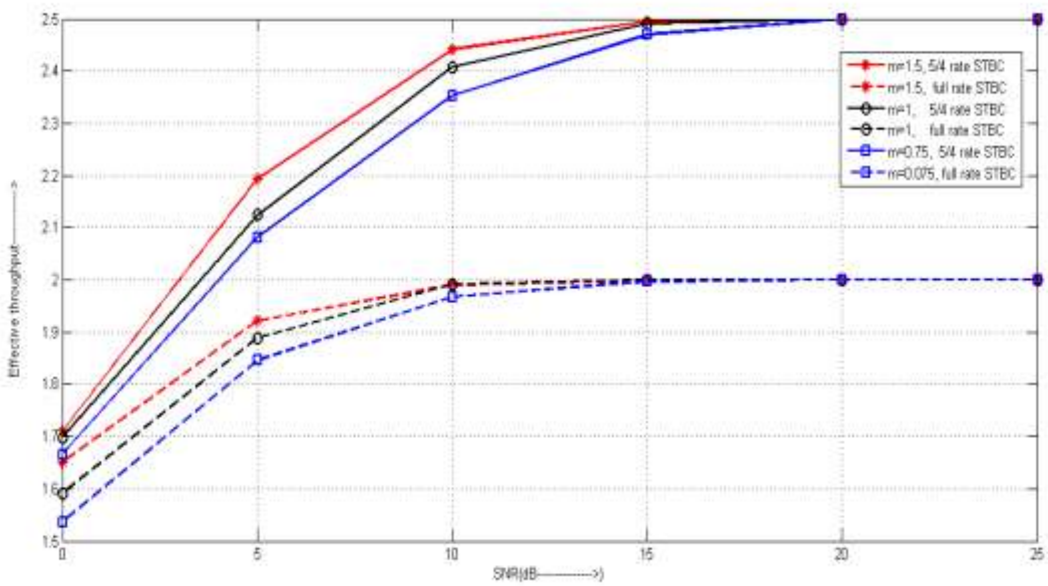

Fig. 2 Performance of Alamouti STBC and High rate STBC in m-Nakagami fading channel for frequency flat condition

Rayleigh fading channel is special case of Nakagami-m fading channel when m=1. Fast fading occurs if the coherence time is smaller than the symbol duration of the signal (T_s>T_c) this is the case when m<1, such channels become time varying and within symbol duration rapid changes occur in impulse response of the channel, In STBC systems an assumption is made that channel impulse response remain same for two consecutive symbol. Practically it is not the case for m<1. Therefore performance of STBC or High rate STBC degrades for m<1 as compared to m≥1.

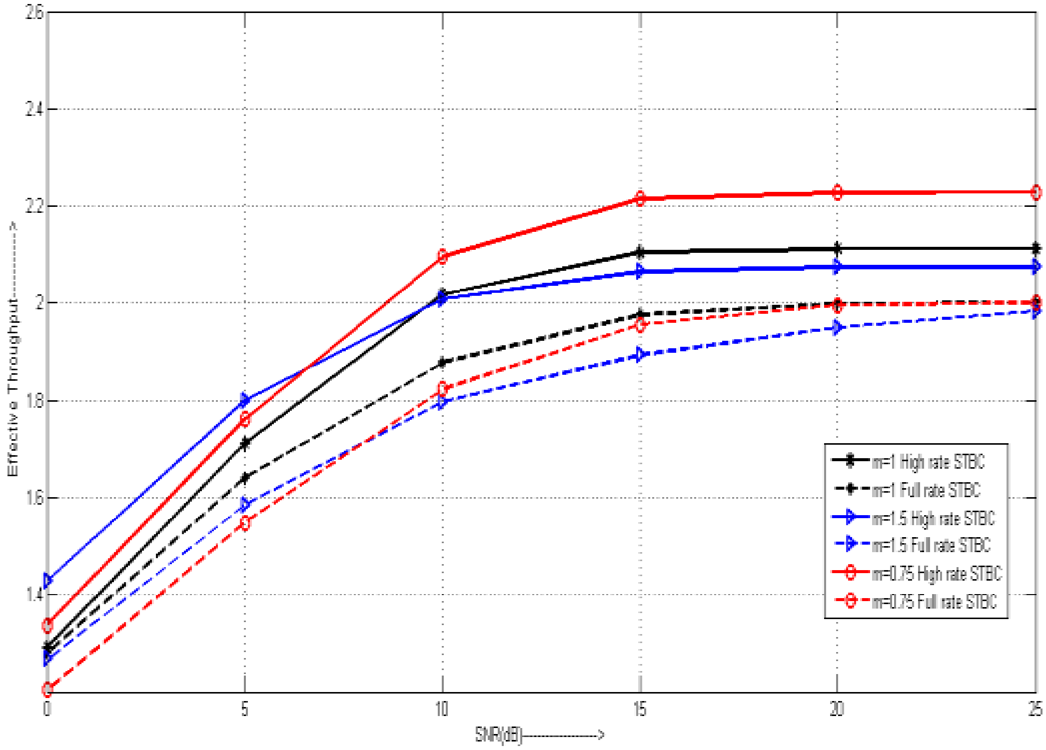

Fig. 3 Performance of proposed receiver for Alamouti STBC and High rate STBC in m-Nakagami fading channel for frequency selective condition.

Fig. 2 shows comparisons of High rate STBC and Alamouti STBC for different values of m for frequency flat condition. We seen that at lower value of SNR for m>1 effective throughput is high in case of both high rate STBC as well as full rate STBC as compared to m=1and effective throughput is low for m<1 compared to m=1for both systems. We also seen that effective throughput of High rate at high SNR is 2.5 becomes constant where as in full rate STBC get effective throughput 2 at high value of SNR.

Fig. 3 shows performance of proposed low complexity zero forcing for frequency selectivity of channel. At high values of SNR (e.g. 6dB to 20dB) proposed low complexity ZF receiver gives better effective throughput for the value of m<1, for m=1 effective throughput is between m<1 and m>1. Whereas at lower values of SNR (e.g. 0dB to 6dB) proposed receiver achieves better effective throughput for the value of m>1.

With the help of proposed receiver at higher values of SNR full rate STBC achieves effective throughput like in case frequency flat condition by reducing complexity at receiver. For m=1 full rate STBC achieves better performance compared to m<1 and m>1.

Conclusion:

We proposed a low complexity zero forcing receiver which achieves better effective throughput as compared to full diversity STBC for m>1. Proposed receiver reduces the complexity of receiver by making the off diagonal element zero of matched filter. It can be further extended for $\frac{9}{8}$ rate STBC proposed in [3].

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